DTU Library

Long reach and enhanced power budget DWDM radio-over-fibre link supported by Raman amplification and coherent detection

Caballero Jambrina, Antonio; Guerrero Gonzalez, Neil; Fernandez, Amaya; Orlando, Ferney; Zibar, Darko; Tafur Monroy, Idelfonso

Published in:
35th European Conference on Optical Communication, 2009. ECOC '09.

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

Long Reach and Enhanced Power Budget DWDM Radio-over-Fibre Link Supported by Raman Amplification and Coherent Detection

A. Caballero[(1)], N. Guerrero [(1)], F. Amaya[(1,2)], D. Zibar[(1)], I. Tafur Monroy[(1)]

[(1)] Department of Photonics Engineering, Technical University of Denmark, Lyngby, Denmark,acaj@fotonik.dtu.dk
[(2)] GIDATI, Universidad Pontificia Bolivariana, Medellin, Colombia, foamaya@javerianacali.edu.co

Abstract We report on a scalable and enhanced power budget radio-over-fibre system for hybrid-wireless access networks operating at *12.5 GHz DWDM spacing for 5 GHz RF carriers over a* 60 km fibre link with Raman amplification**.**

Introduction

Radio-over-Fibre (RoF) transmission systems are currently finding an application in Hybrid Wireless-Optical Broadband-Access Network (WOBAN)[1].The WOBAN network provides the advantages in terms of high capacity and transparency of a Passive Optical Network (PON) with the flexibility and cost-savings of a wireless network[1,2]. However, superimposing a conventional optical intensity modulated wireless signals over a PON architecture demands careful design to accommodate required optical power budgets, optical bandwidth efficiency and overall system linearity[2]. The use of optical phase modulation for RoF systems offers several advantageous features in WOBAN, such as enhanced linearity[3,4] and absence of required driving bias in the optical Phase Modulator (ΦM). This allows for passive antenna base stations with potentially lower power consumption compared to traditional approaches. In this paper, we propose and experimentally demonstrate a RoF system addressing the challenges of power budget, spectral efficiency and linearity based on optical phase modulation and digital coherent detection. We also propose to use fibre distributed Raman amplification and its advantageous features (high OSNR, possible centralize pump location, wide spectral gain range) to extend reach and scalability of the fibre access link and benefit from the enhanced receiver sensitivity. We report on the experimental demonstration of a combined wireless and fiber link of 5 RF channels at 5 GHz carrier frequency, 250 Mbps BPSK modulated, over a 12.5 GHz spaced DWDM link.

WOBAN Scenario

Figure 1 shows the description of the considered

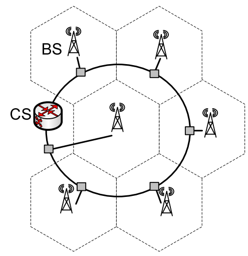

Fig. 1: Proposed WOBAN scenario

WOBAN scenario. An optical fiber ring connects multiples Base Stations (BS) to a Central Station (CS) where signal detection and demodulation take place. Each BS may lie some distance away, e.g. 20 km, from the feeder fibre ring and may use a specific assigned wavelength and conventional single mode fibre (SMF) while the feeder ring may use a Non-Zero Dispersion Shift Fibre (NZDSF) that in combination with Raman amplification offers low chromatic dispersion and compensation of transmission loss, with enough power budget for proper detection. At the receiver side, optical coherent detection is used and channel selection is performed by proper wavelength tuning of the local laser oscillator. A DSP receiver is envisaged to perform linear phase demodulation.

Setup Description

The experimental setup is shown in Fig. 2. The transmitter consists on 5 tuneable Distributed Feedback Laser (DFB) with an average output power before ΦM of +1 dBm and ~3 MHz linewidth. The wavelengths are from 1552.22 nm to 1552.62 nm, following the 12.5 GHz ITU grid spacing. A 250 Mbps BPSK is generated using an Arbitrary Waveform Generator (AWG) at 1.25 GSa/s that drives a Vector Signal Generator (VSG), which performs up conversion to the 5 GHz carrier Radio-Frequency

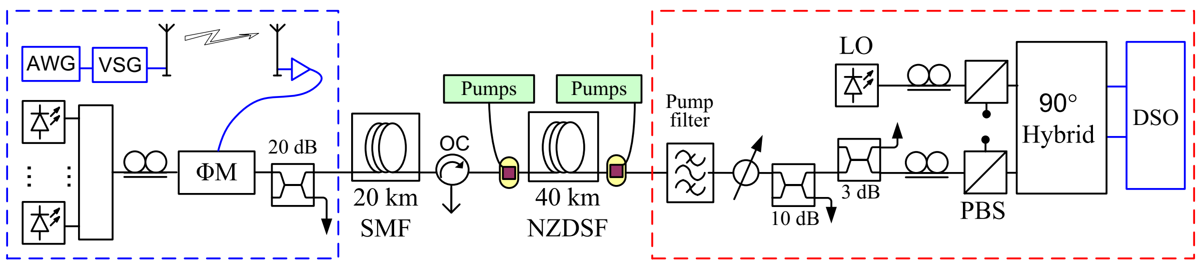

Fig. 2: Experimental setup description

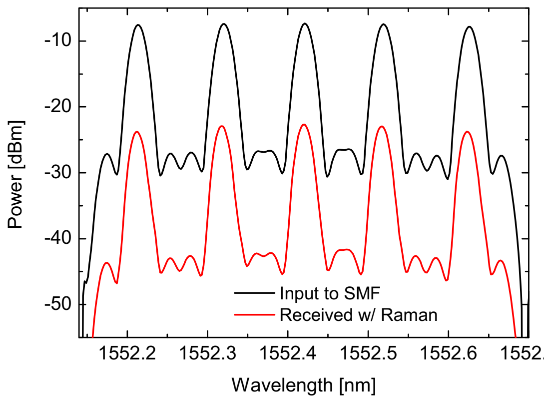

Fig. 3: Spectrum of WDM channels

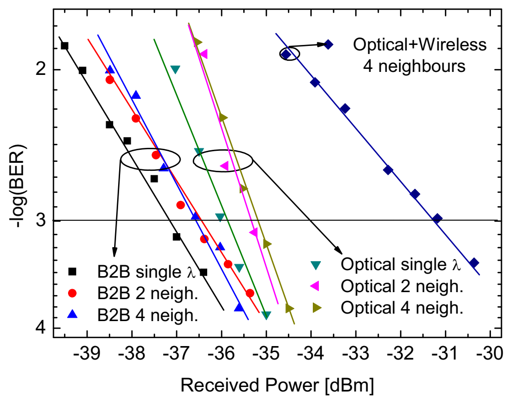

Fig. 4: BER curves for B2B, fiber transmission, fiber transmission with wireless link

(RF). The output power of the VSG is 8 dBm and it is used to drive an omnidireccional antenna with 12 dBi gain. Due to the in-door laboratory space limitations, 2 m away, another similar antenna detects the signal and, after a 37 dB gain RF amplifier, drives the ΦM with 6 dBm RF power. The optically phase modulated signal is transmitted through 20 km of SMF before entering the 40 km NZDSF feeder ring span. To compensate for the ring fiber losses, a bidirectional distributed fiber Raman amplification was employed with co pumping wavelengths at 1455 nm and 1427 nm, and counter pumping at 1463 nm. The pump powers were 200 mW, 100 mW and 240 mW respectively, with an average on-off Raman gain of 12 dB. A circulator and a wideband filter are used to reject the pumps wavelength into the transmitter and receiver, respectively. As a Local Oscillator (LO), a tunable external cavity laser is used, with ~100 kHz linewidth and 0 dBm input power to the 90° optical hybrid. Both signals are passed through Polarization Beam Splitters (PBS) so the beating of both lasers is maximized. In practice, a polarization diversity scheme or polarization tracking can also be implemented. The resultant in-phase and quadrature signals are detected with two pairs of balance photodiodes, with 7.5 GHz bandwidth. The detected photocurrents are digitalized using a sampling oscilloscope at 40 Gs/s (Agilent Infinium DSO91304A) for offline signal processing. The demodulation algorithms[4] consists on a carrier recovery digital PLL, linear demodulation for phase extraction, carrier recovery and symbol decision.

Experimental Results

The measured optical spectrum is shown in Fig. 3. For comparison purposes we relate the performance relative to the central wavelength channel (1552.42 nm) and its neighbour channels. Further, we assessed the penalty in Bit Error Rate (BER) for detecting the central wavelength alone, and for the case of simultaneous transmission of two and four neighbouring channels spaced 12.5 GHz. The BER comparison level is set to 10^{-3}, corresponding to the lower bound for Forward Error Correction (FEC) algorithms.

Fig. 4 shows the measured results for Back-to-Back (B2B), after the fiber link, with direct modulation of the ΦM from the VSG (no air link) and after 2 m wireless transmission. A penalty of 0.5 dB is incurred from single wavelength to two 12.5 GHz spaced neighbours, whereas almost no additional penalty is measured for four 12.5 GHz spaced neighbours. A penalty of only 1.5 dB is shown from B2B to 60 km fiber transmission link. We can also observe that in our experiment the main source of penalty is due to the two closest channels and not by the number of channels, indicating low or no cross phase modulation (XPM) during fibre transmission. The wireless link introduced a measured 5.5 dB penalty, however signal detection was still possible. Our DSP receiver did not include any compensation schemes to deal with signals distortions due to the wireless link nor for fibre chromatic dispersion, and therefore performance improvement is still possible.

Conclusions

We have experimentally demonstrated the first wireless and fiber link using optical phase modulation supported by coherent detection and a DSP receiver. 5 DWDM channels spaced 12.5 GHz where transmitted through the fiber, with receiver sensitivity above -30 dBm for 60 km fibre transmission, including 2 m wireless link. To compensate the attenuation of the 40 km NZDSF feeder ring distributed Raman amplification was used. This result indicates the prospects of using coherent detection and DSP for RoF links in WOBAN due to its enhanced received sensitivity, linearity and spectral efficiency.

References

1 S. Sarkar et al., J. Lightwave Technol. **25**, 3329-3332 (2007)
2 Z. Jia et al., J. Lightwave Technol. **25**, 3452-3471 (2007)
3 T. R. Clark et al., PTL **19**, 1206-1208 (2007)
4 D. Zibar et al., PTL **21**, 155-157 (2009)